Search for Heavy, Long-Lived Neutralinos that Decay to Photons at CDFII using Photon Timing

(to be submitted to PRD)

Paul Geffert, Max Goncharov, Slava Krutelyov*, Eunsin Lee, Rishi Patel, David Toback and Peter Wagner*****

*Now postdoc at UCSB
** REU student from NYU
*** Now postdoc at Penn

History

- Delayed Photon Analysis published in PRL
  - PRL 99, 121801 (2007)
- Goal: Publish more details in a full PRD
  - CDF Note 9171
- Godparents: F. Bedeschi, H. Budd and A. Messina
- ***No New Results***

Outline

Since we've done this once already, we were requested to keep it short and sweet

- Short Overview of the Motivation and Theory
- Brief Summary of the Analysis
- Conclusion

Supporting Documentation: CDF Notes 7515, 7918, 7928, 7929, 7960, 8015, 8016

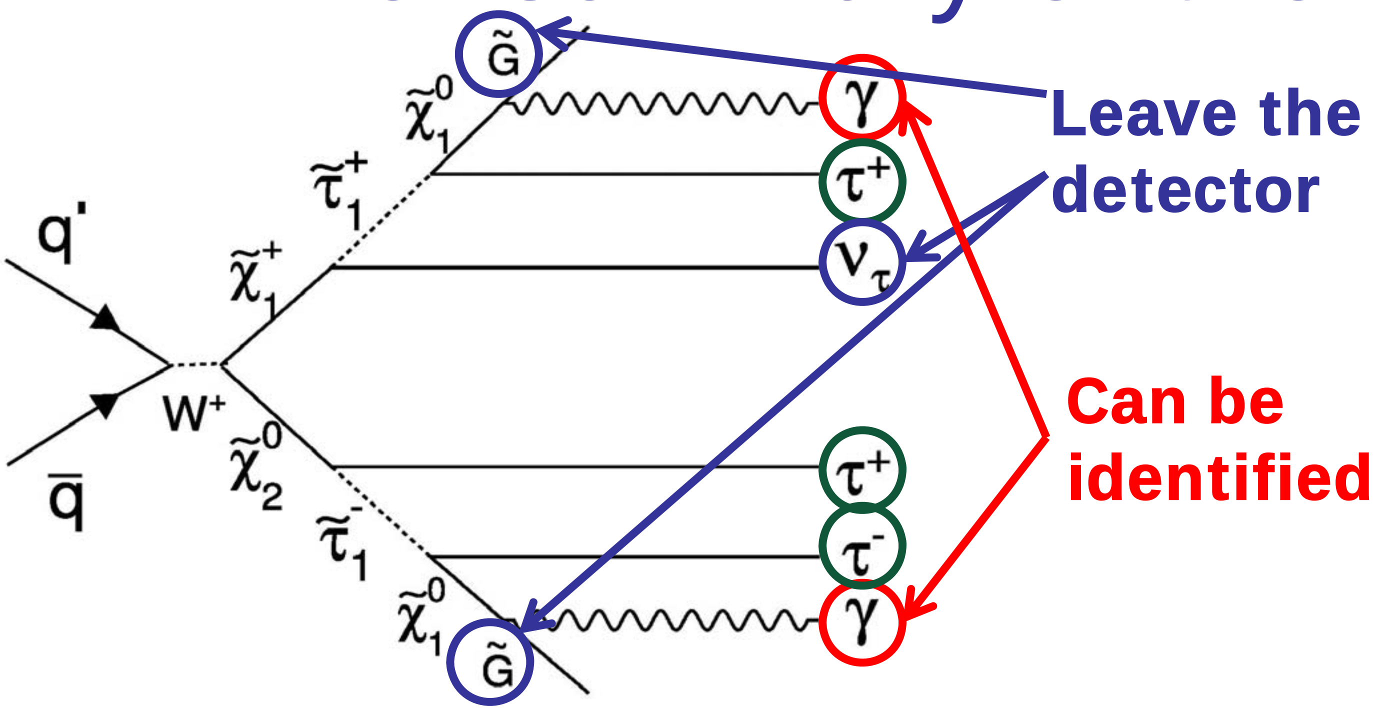
Motivation and Theory

- GMSB models predict heavy neutralinos that decay to photons (see next slide)
- $ee\gamma\gamma + \not{E}_T$ candidate event at CDF in Run I
- First search for heavy, long-lived particles that decay to photons at a hadron collider

GMSB Models

- The lightest neutralino is the NLSP and decays into a gravitino and a photon
- For much of the parameter space the neutralino decay time can be ~ns
- At the Tevatron neutralinos are pair produced from $\chi_1^{\pm}\chi_1^{\mp}$ or $\chi_1^{\pm}\chi_2^{0}$

Brief Summary of the Analysis



Signature

$\Rightarrow \not{E}_T$

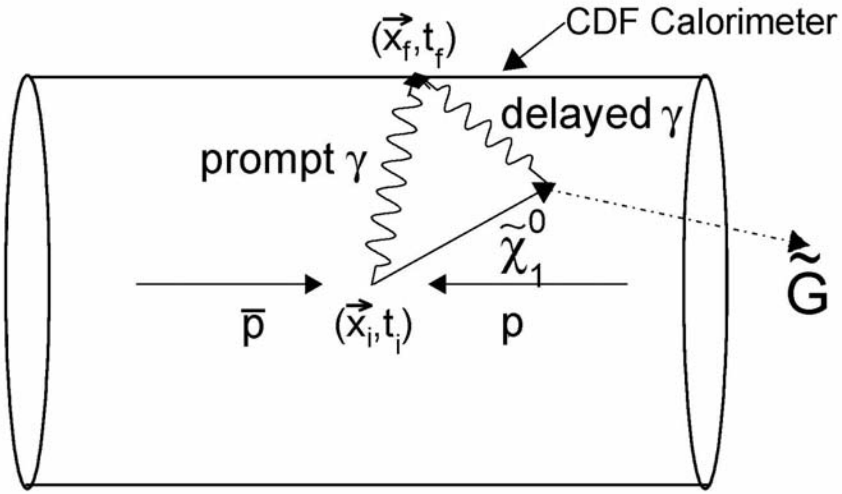
Jets

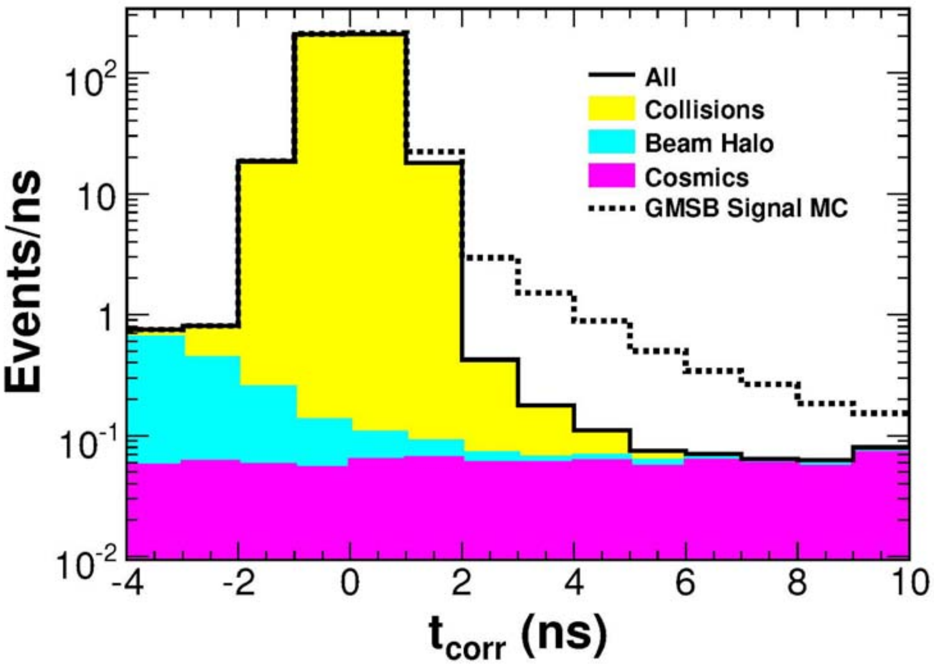
$\Rightarrow \gamma\gamma$ or γ

- $\gamma + \not{E}_T + \text{jets}$ analysis is sensitive to ns lifetimes while $\gamma\gamma + \not{E}_T$ analysis is sensitive to prompt neutralino decays

Toback and Wagner, PRD 70, 114032 (2004)

Event Schematic and Time Distribution

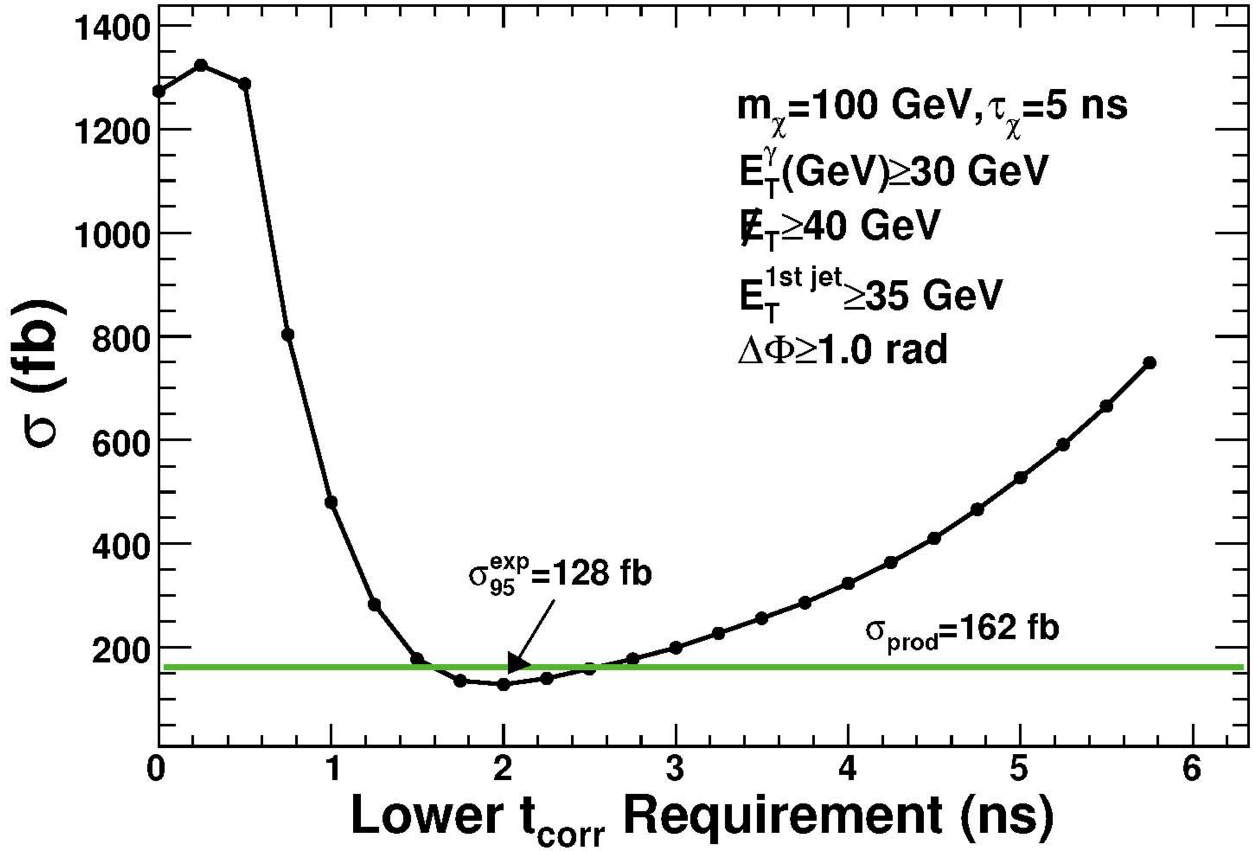




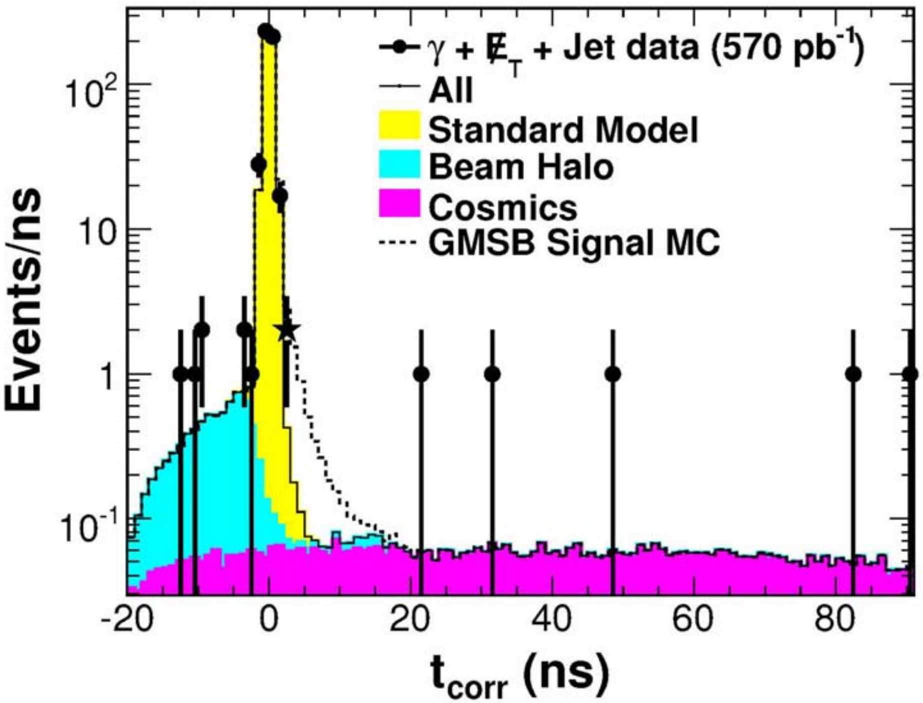
- Left- Schematics of a long-lived neutralino decay into a gravitino and a photon
- Right- The corrected time distribution for a GMSB example point as well as the non-collision and SM backgrounds

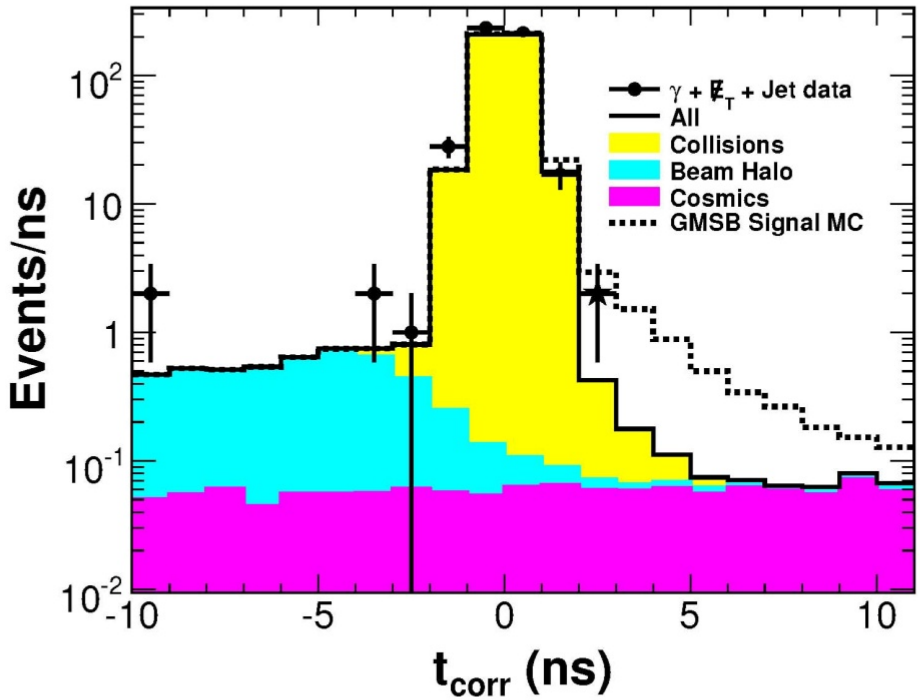
Analysis Optimization

The expected 95% C.L. cross section limit as a function of the lower value of the timing requirement for a GMSB example point



The Data...
Timing Distribution

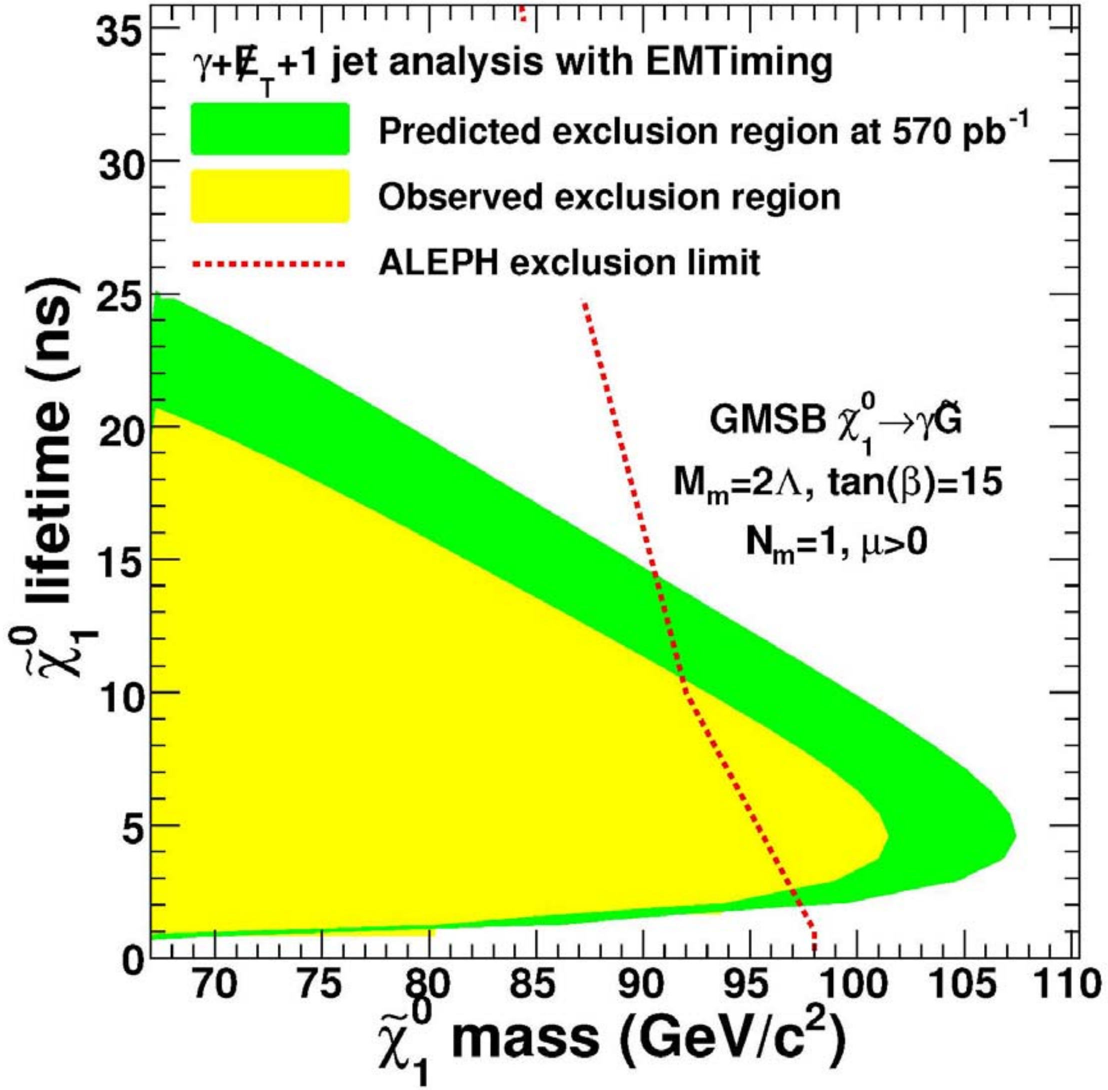




- Left- The timing distribution for the signal and all backgrounds
- Right- A zoomed in view of the signal region, [2,10] ns
- Two events are observed in the signal region, consistent with the background expectation of 1.3±0.7 events

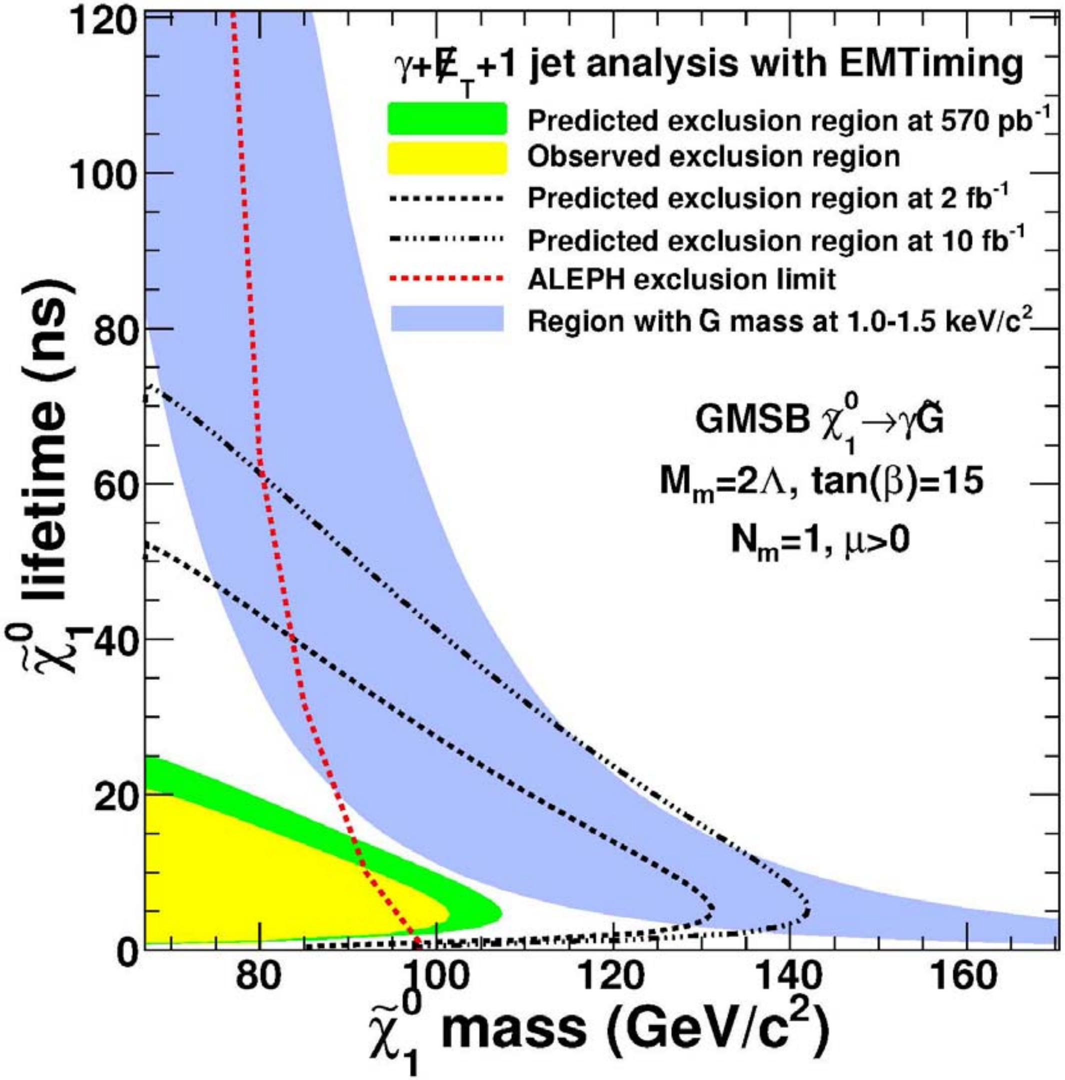
Exclusion Region

- Expected and observed 95% C.L. exclusion region along with LEP limits
- Highest mass reach is 108 GeV (expected) and 101 GeV (observed) for a lifetime of 5 ns.



Expected Sensitivity for 2 fb^{-1} and 10 fb^{-1}

- Background scaled with luminosity
- The shaded band shows the cosmologically favored parameter space

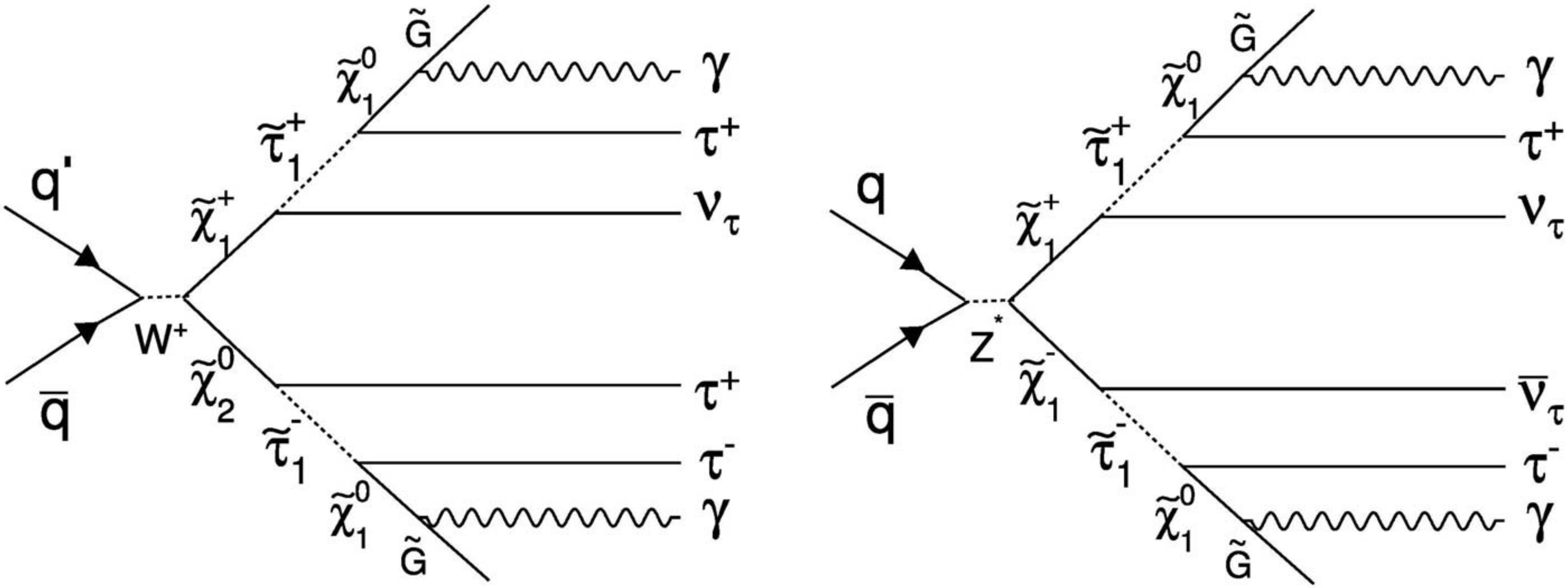


Conclusion

- Both readings of the PRD are complete and the GPS have signed off
- Next generation analyses with more data and new ideas/techniques are in progress

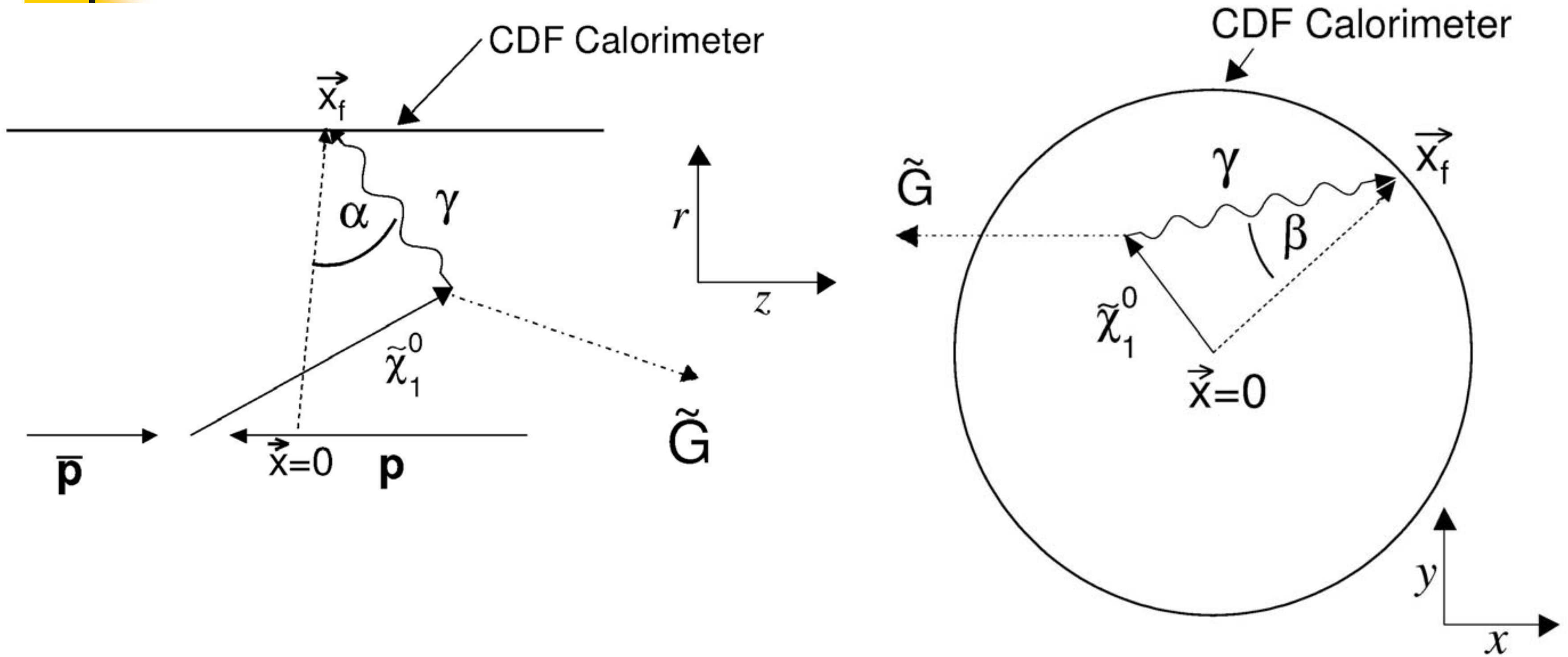
Backup slides

PRD Figure 1- Feynman Diagrams



- Feynman diagrams of the dominant production processes at the Tevatron
- Use SPS 8 GMSB model line (Eur. Phys. J. C 25, 113 (2002)): $\tan(\beta)=15$, $\mathrm{sgn}(\mu)=1$, $N_m=1$, and $M_m=2\Lambda$

Fig. 3- Photon Can Hit the Calorimeter with a Large Incident Angle



- Left- Definition of α, the projection of the photon incident angle in the (r,z) plane
- Right- Definition of β, the projection of the photon incident angle in the (r, ϕ) plane

Fig. 4- Look at Photon Incident Angles

- Delayed photons have a larger incident angle than promptly produced photons
- Distribution of the total incident angle, ψ, of the photon at the face of the calorimeter

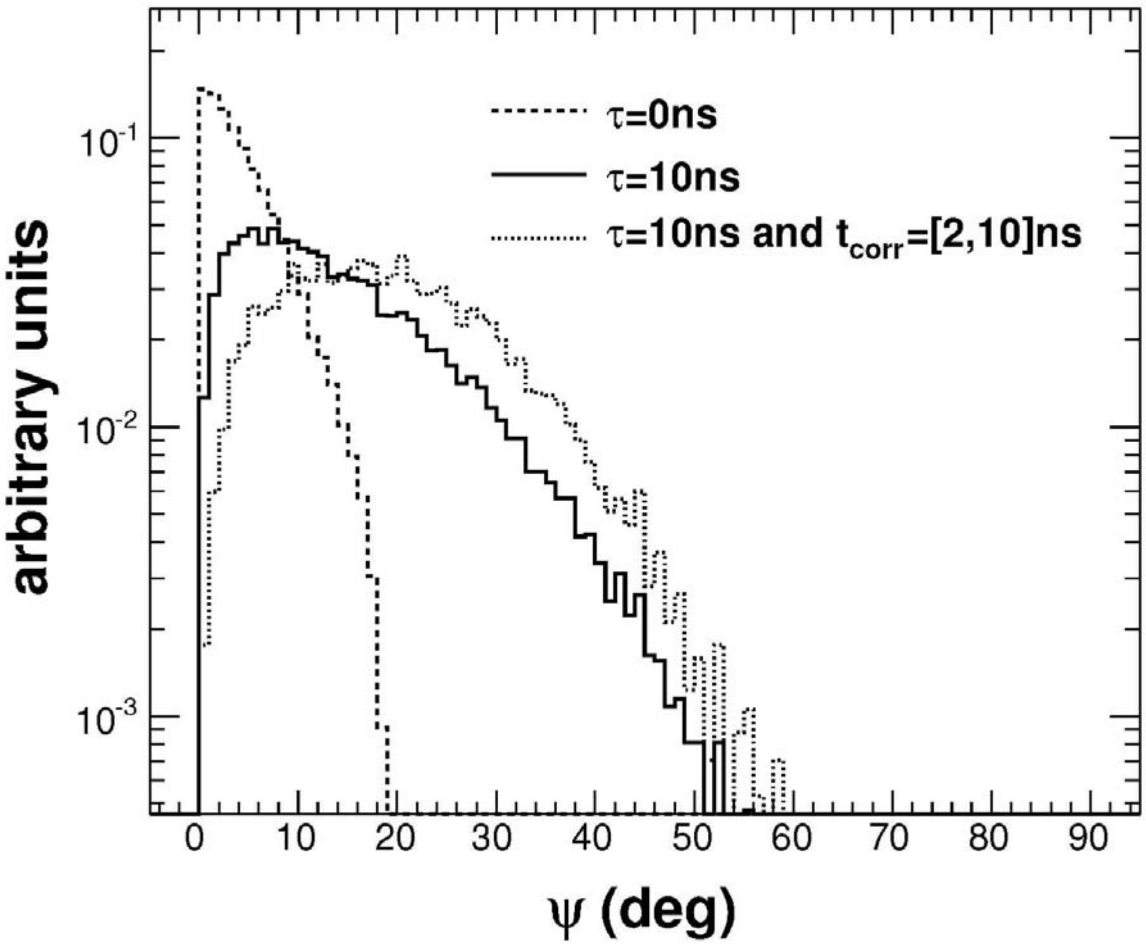
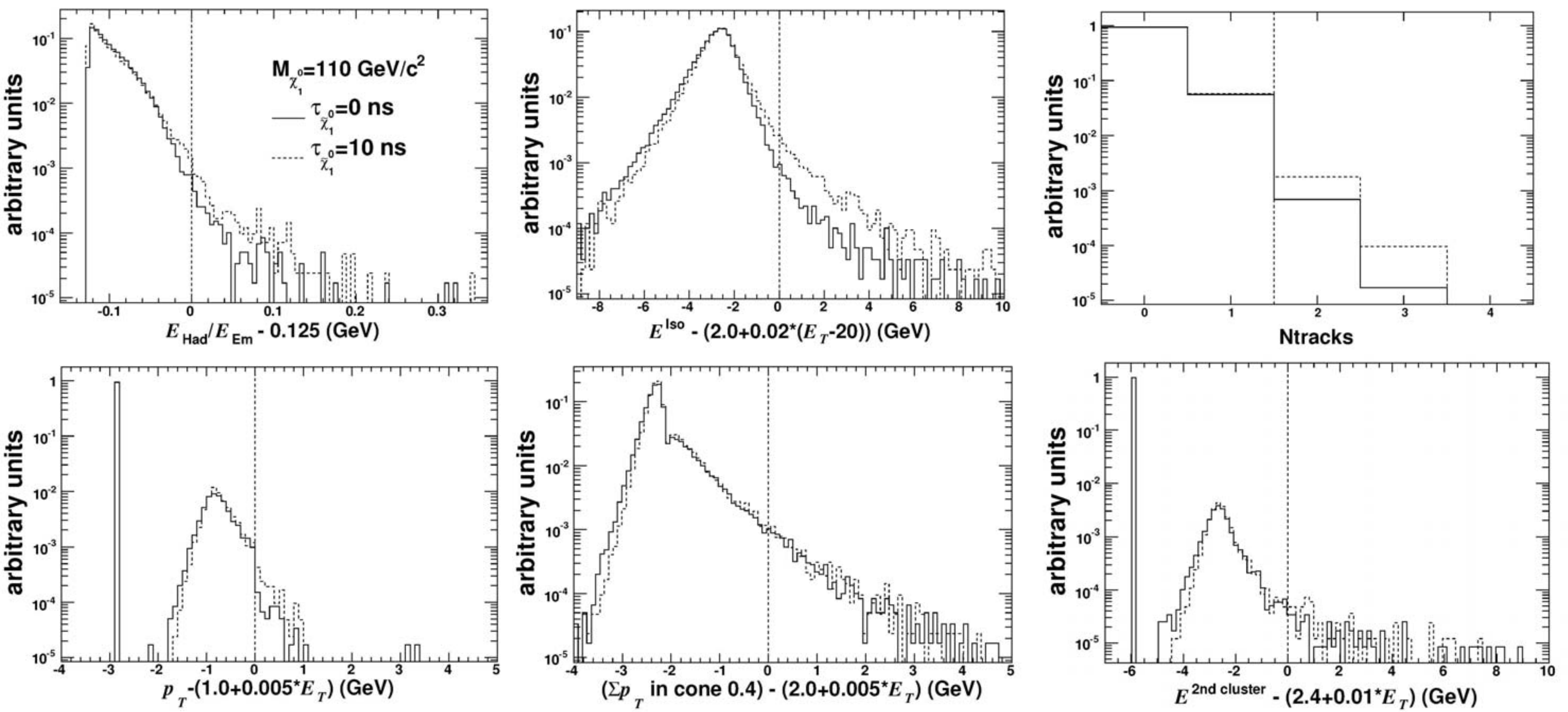
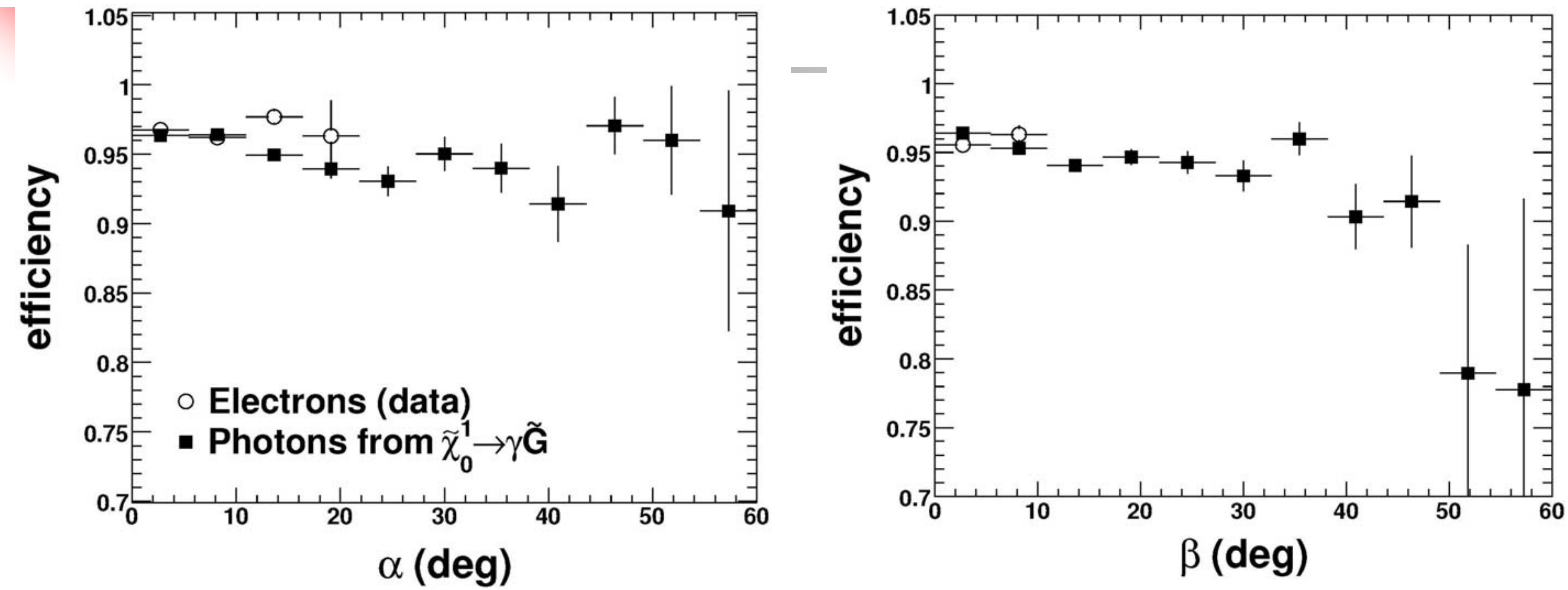


Fig. 5- Compare ID Variables (Long Lifetime vs. 0 Lifetime)



CDFSim ID variable distributions minus their requirement value

Fig. 6- Efficiency vs. Angle, Compare Electrons and Photons from Data and MC



- Left- The efficiencies for e’s and γ’s to pass ID requirements vs. incident angle α
- Right- The same but for β
  - Efficiency falls in β primarily due to the energy isolation requirement; small effect, well-modeled in MC

Fig. 7- New PMT Asymmetry Cut to Kill Spikes

- Compare asymmetry of spikes to real electrons
- Require asymmetry to be less than 0.6

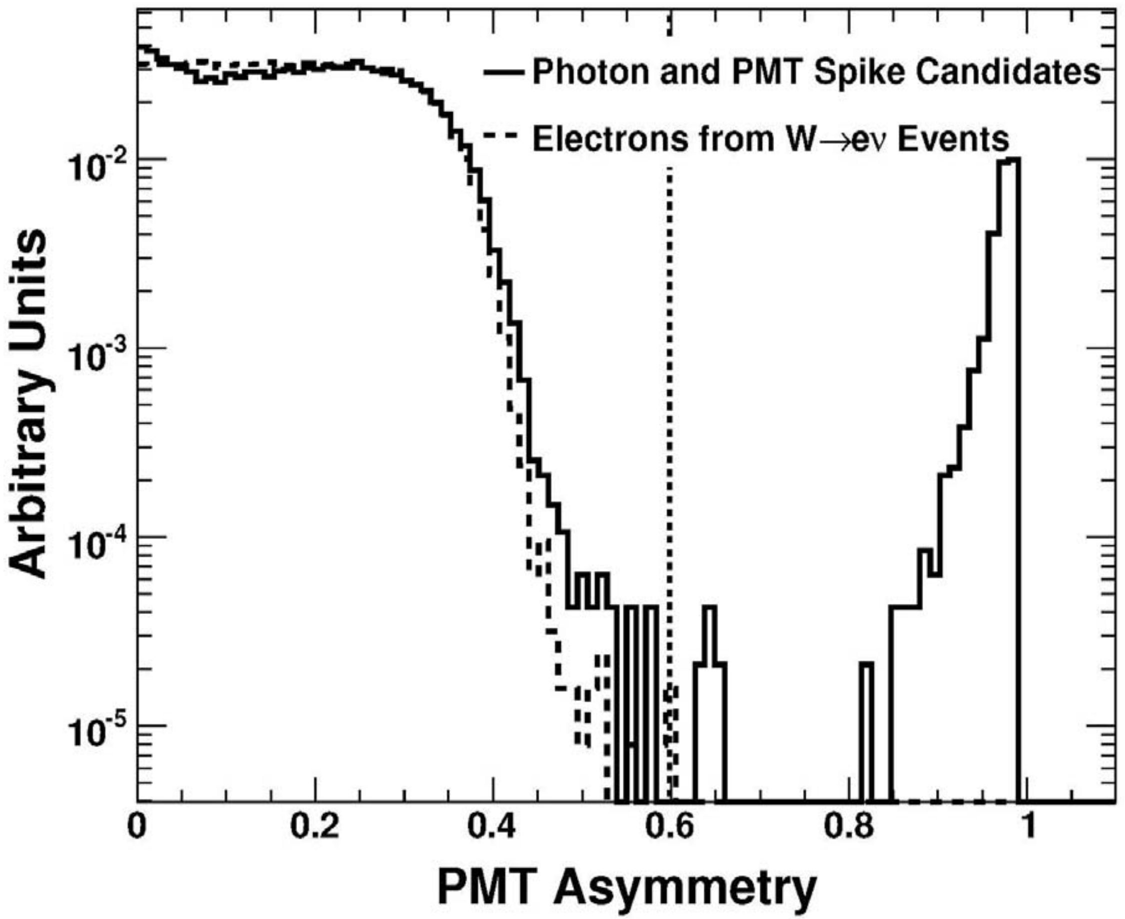
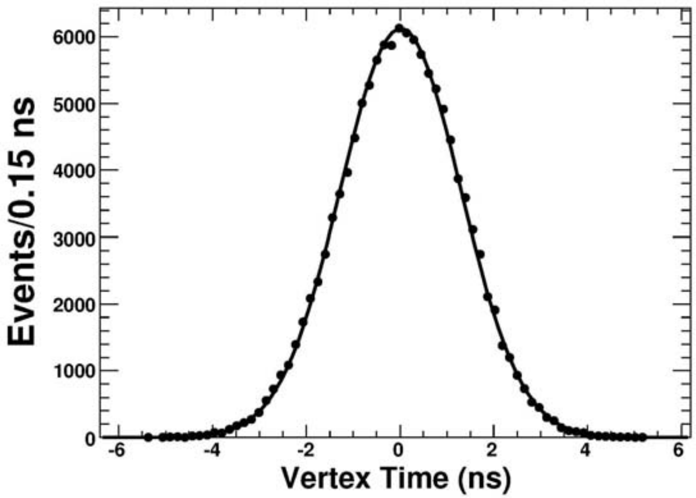
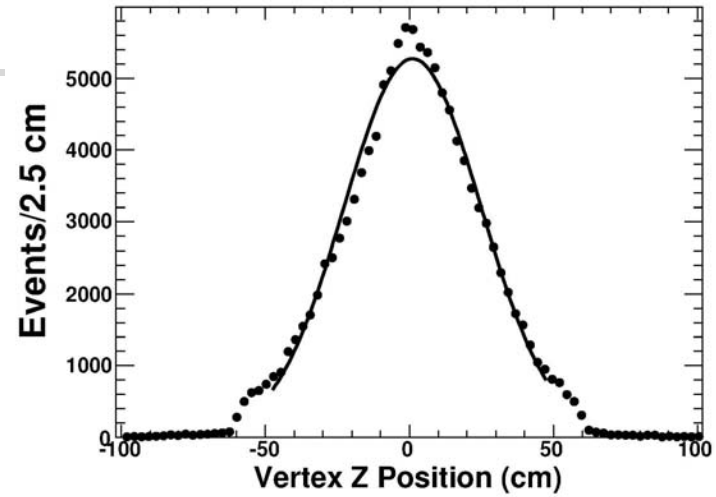


Fig. 8- Vertexing





- The collision time and position for the reconstructed highest Σp_T vertex in $W \rightarrow e\nu$ events
- Also show correlation for fun

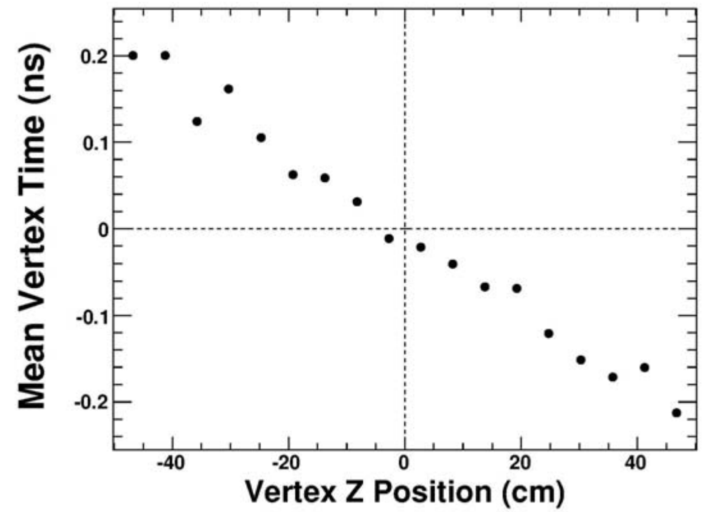
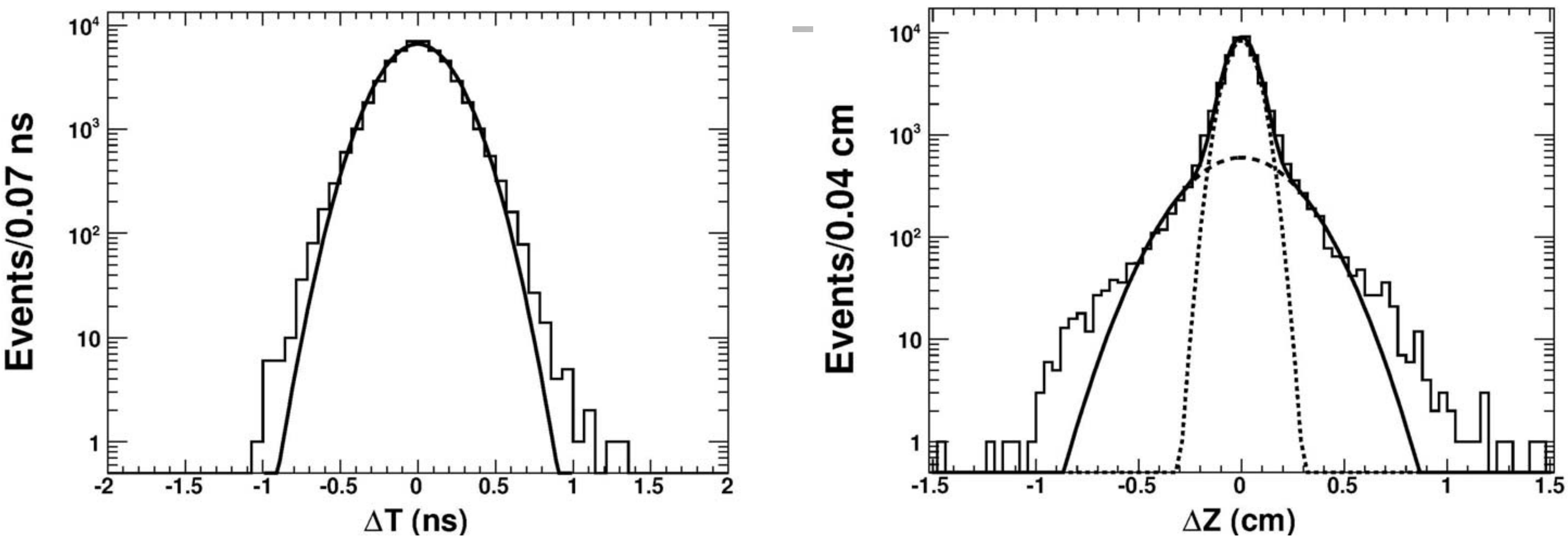
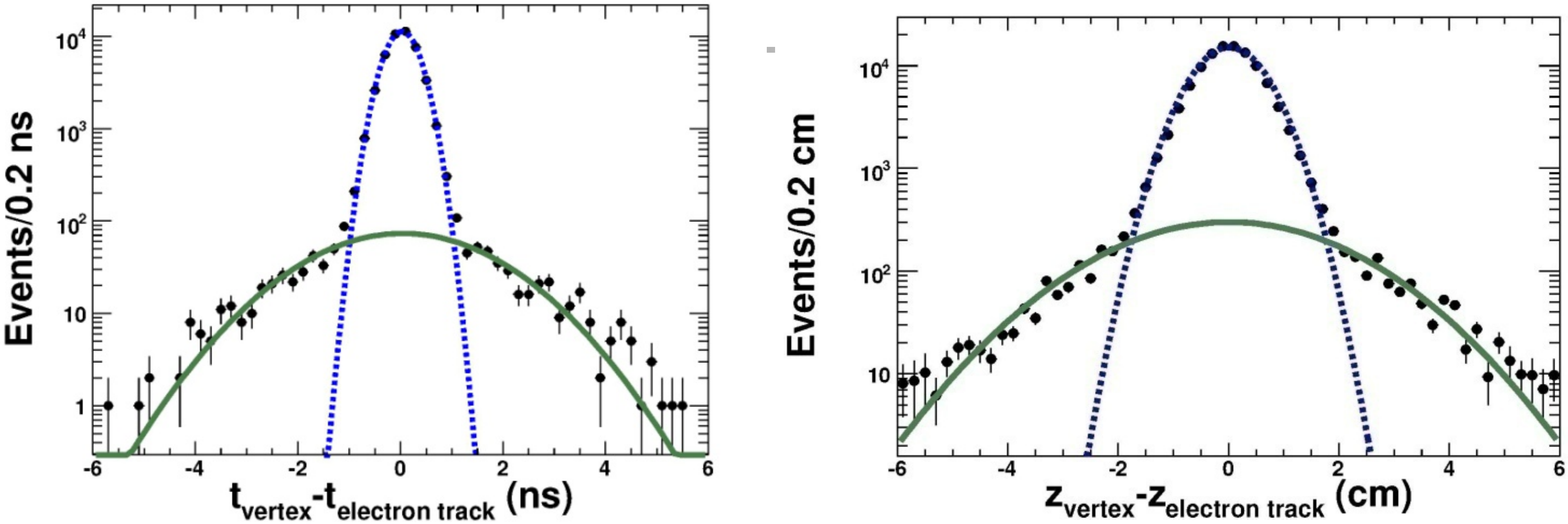


Fig. 9- Vertexing Performance/ Resolution



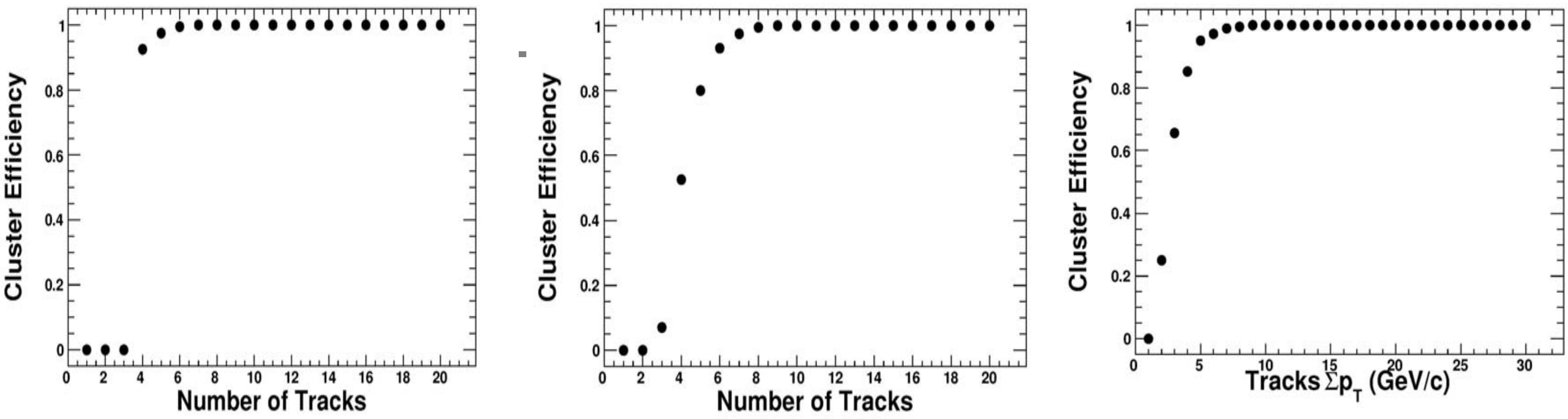
The difference in z and t between two arbitrarily selected sets of tracks from the same reconstructed vertex in a W→eν dataset

Fig. 10- Vertexing Performance continued; Compare Vertex to Electron Track



- The distributions are centered at zero → no clustering bias
- The second Gaussian contains events where the electron is from a second vertex in the event

Fig. 11- Vertexing Efficiency



We require a vertex to have at least 4 tracks and Σp_T > 15 GeV → 100% efficiency

Fig. 12- Check EMTiming Simulation and Show Resolution

Well centered around 0 ns with RMS of 0.64 ns

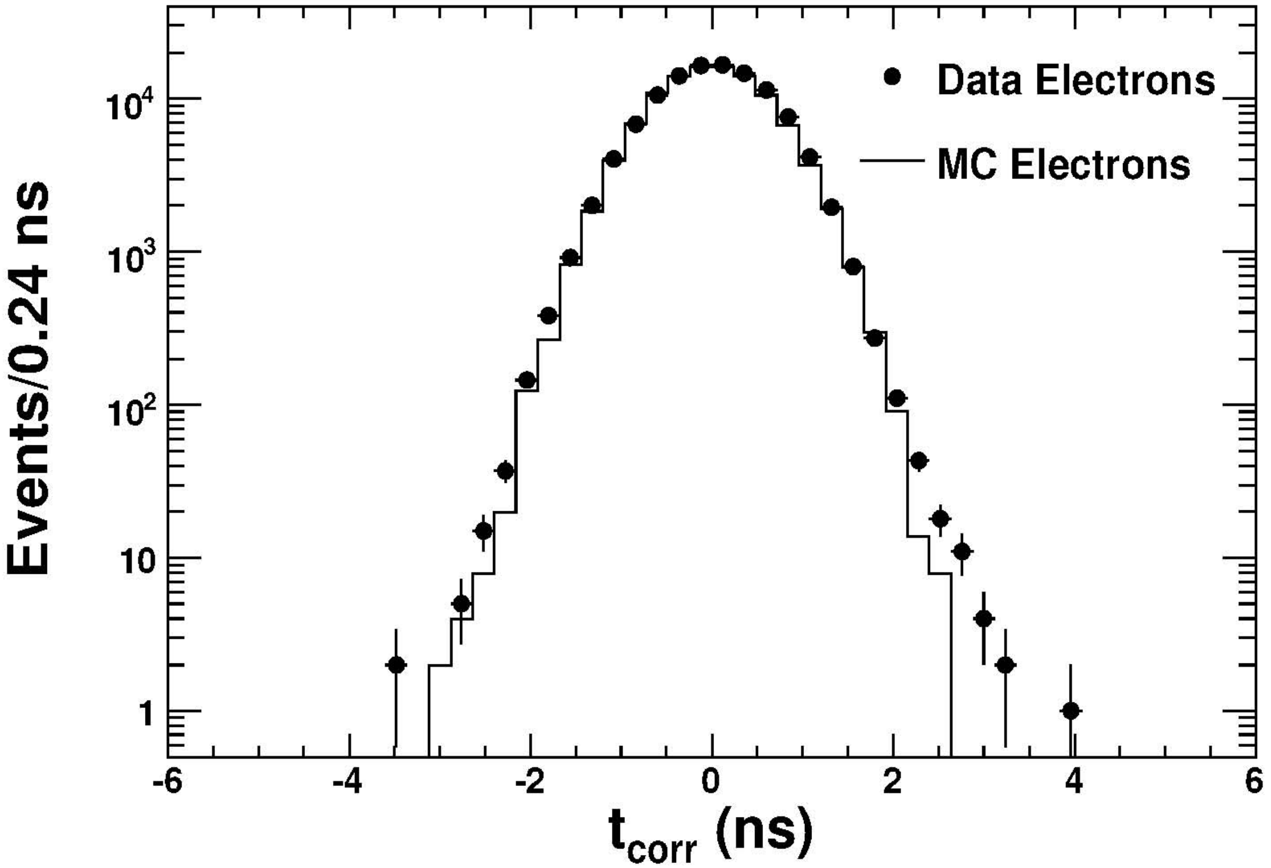
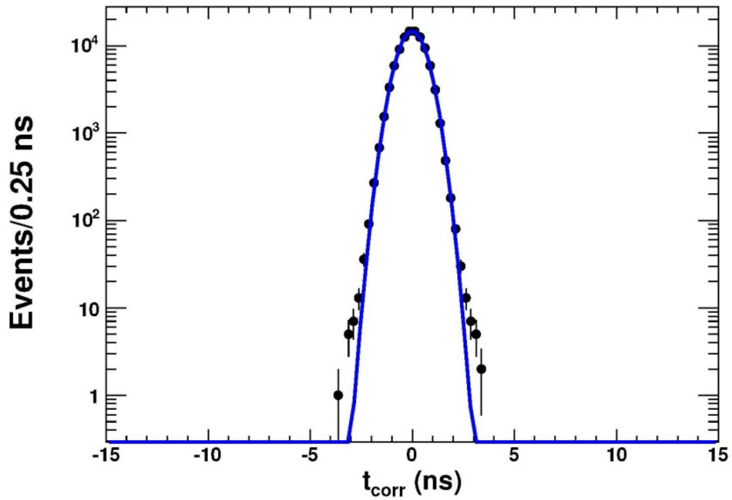
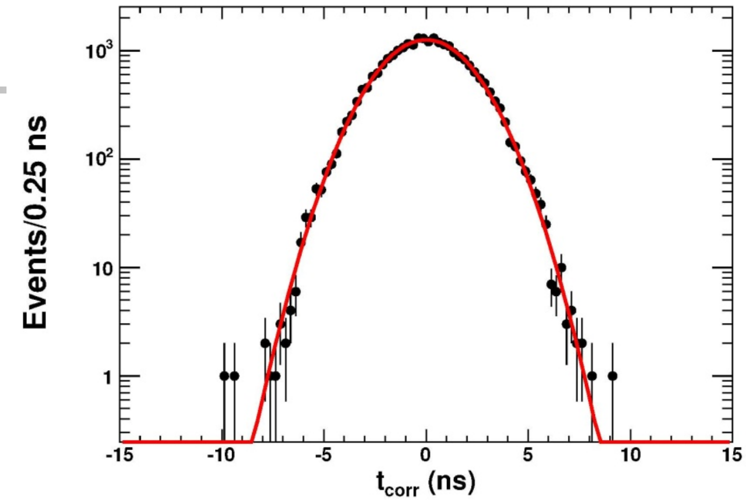


Fig. 13- Timing Distribution for "Right" and "Wrong" Vertex Selection





- Top Left- Electron track matches vertex ("Right Vertex")
- Top Right- Electron anti-matched to vertex ("Wrong Vertex")

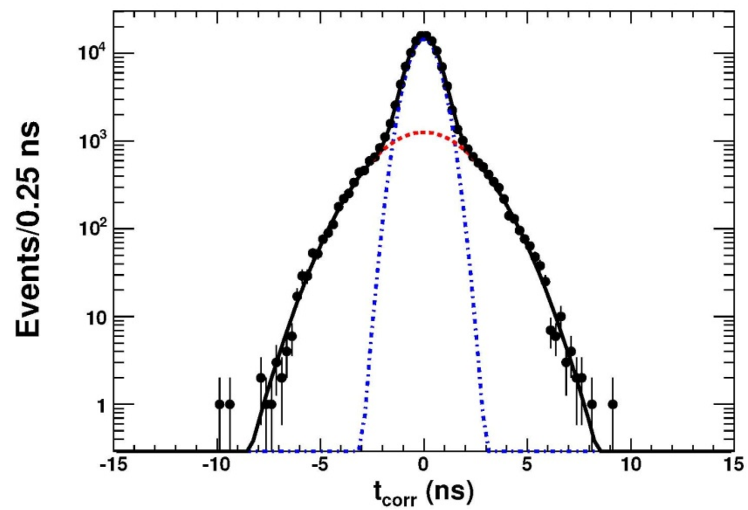
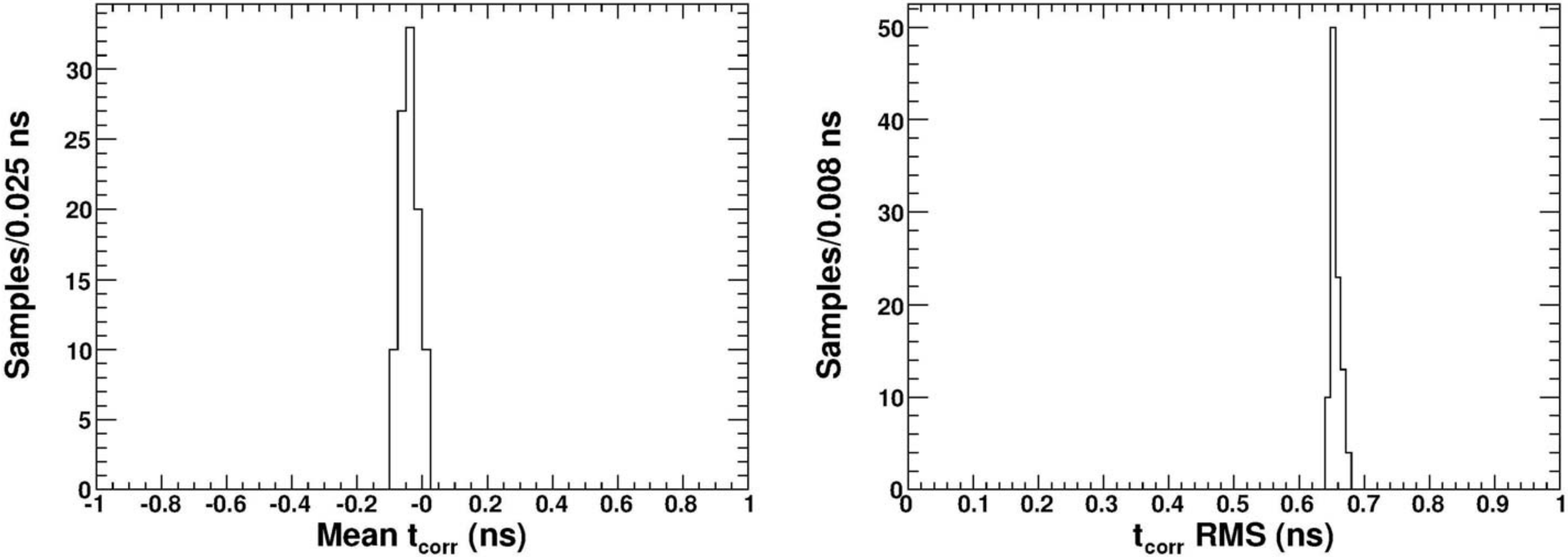
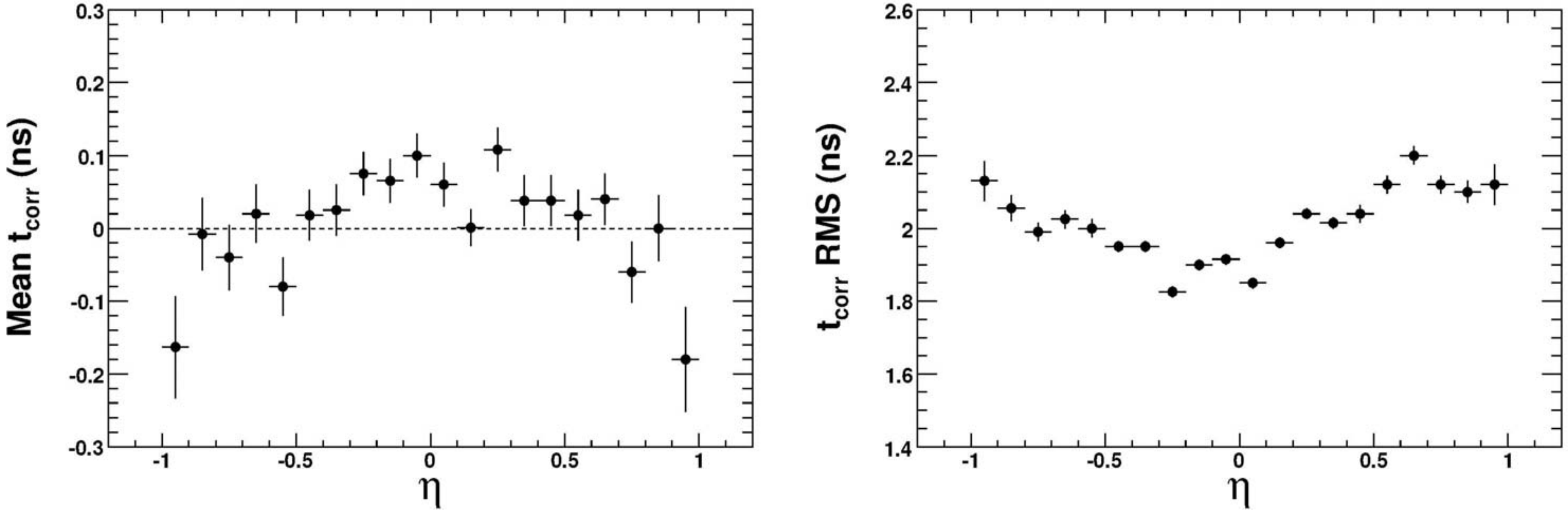


Fig. 14- Systematic Variation of Timing Mean and RMS



Look at the timing distribution for electrons from subsamples of $W \rightarrow e\nu$ + jets events for different requirements on electron E_T, jet E_T, and $\not{E}_T$

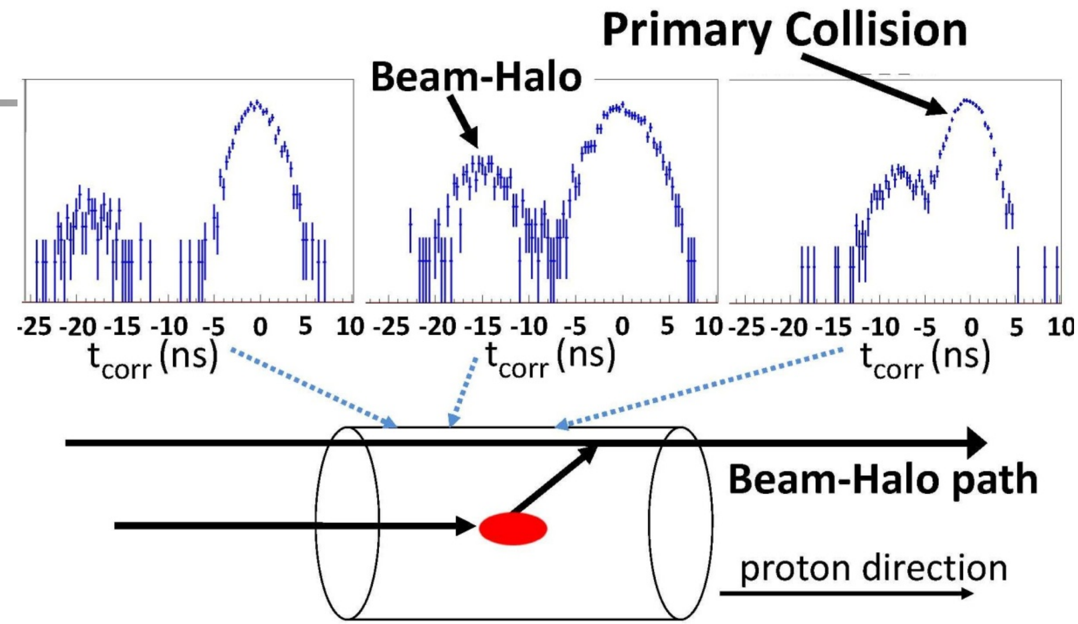
Fig. 15- Systematic Variation of Timing – Wrong Vertex



The mean and RMS of the timing for electrons as a function of η, when the wrong vertex is picked

Fig. 16- Beam Halo

- Illustration of a beam halo event
- Top-The mean corrected time changes as a function of η but is always less than zero
- Bottom-The halo interacts with many hadronic calorimeter towers at high η



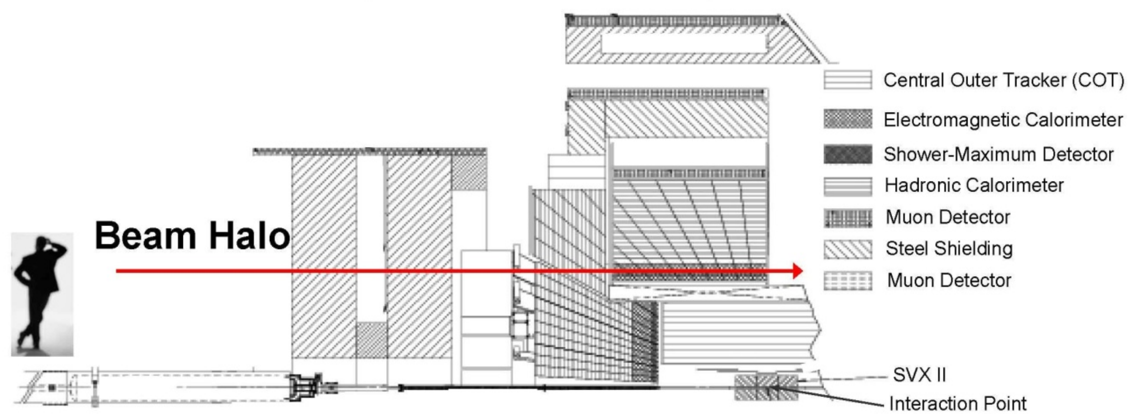


Fig. 17- Beam Halo vs. Cosmics

The variables used to separate cosmic and beam halo backgrounds to create their timing templates

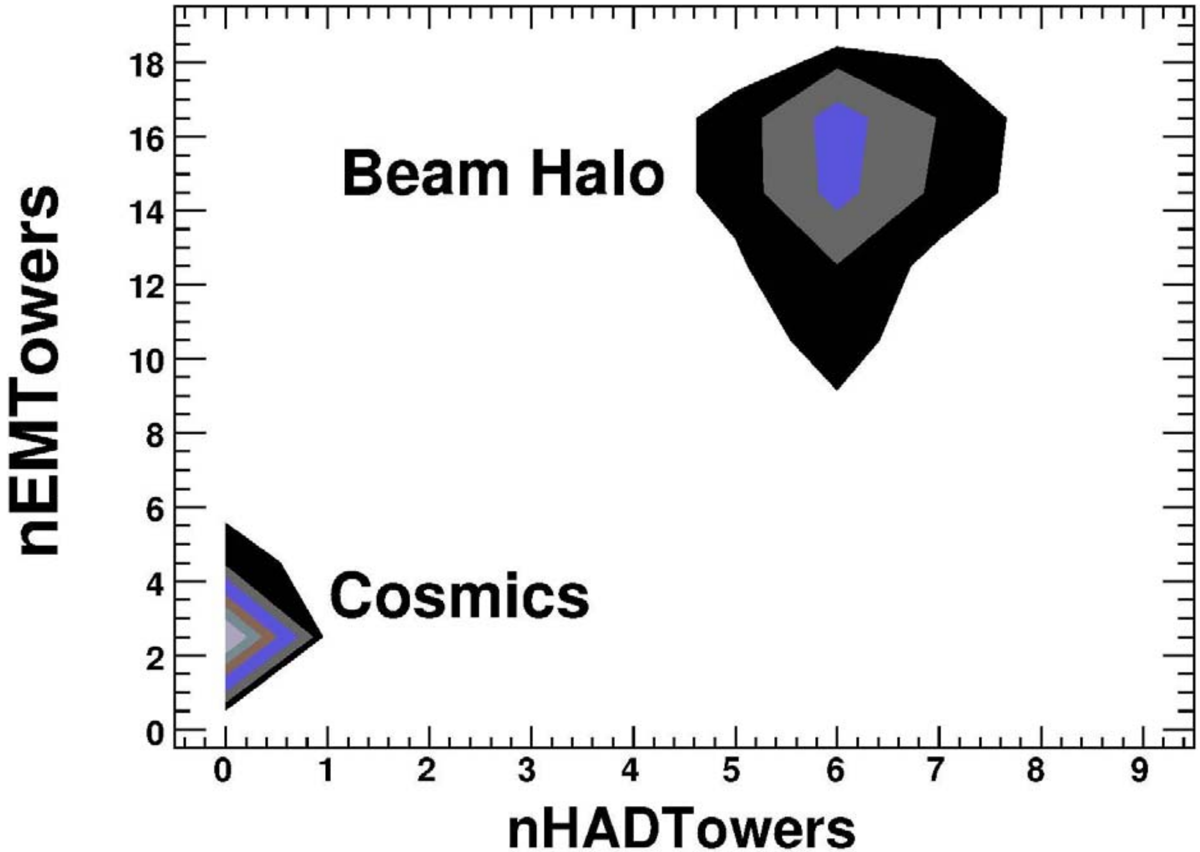
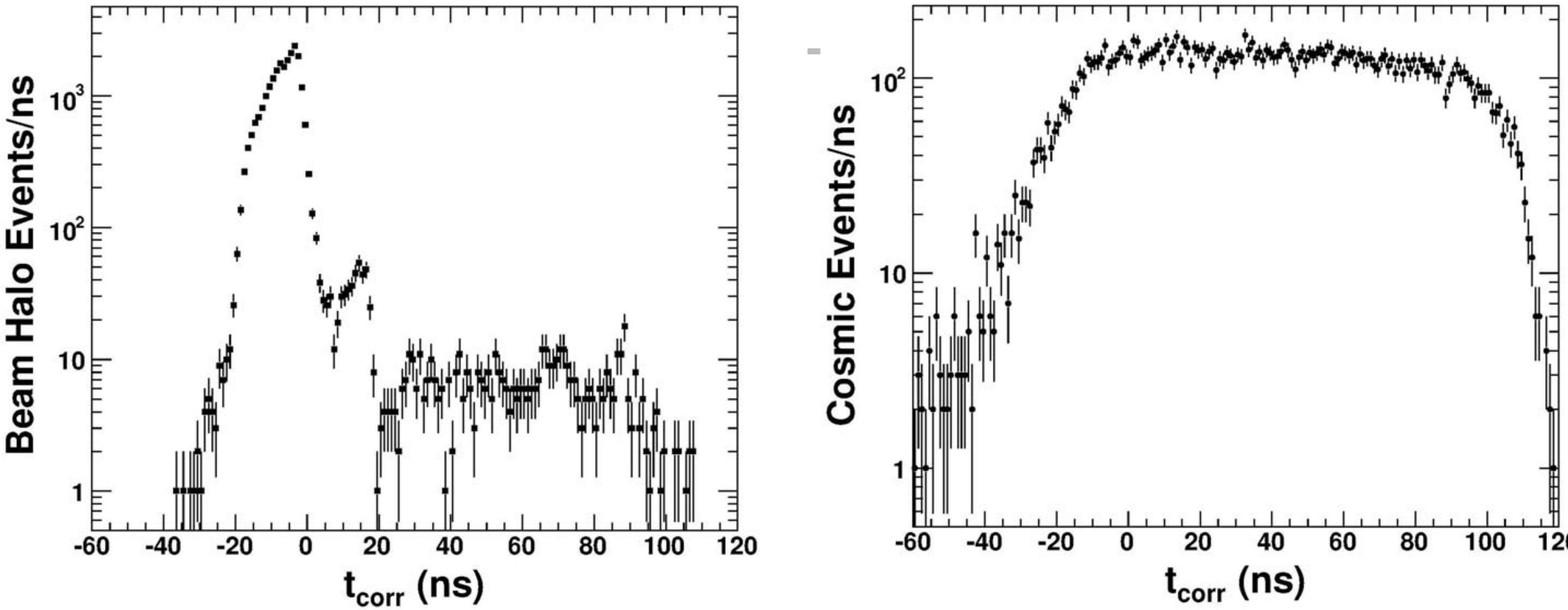


Fig. 18- Timing for Beam Halo and Cosmics



The corrected time distributions for beam halo (left) and cosmic ray (right) backgrounds

Fig. 19- More on Beam Halo

- **Most beam halo photons arrive at $\phi \approx 0$**
- **Use this for background normalization**

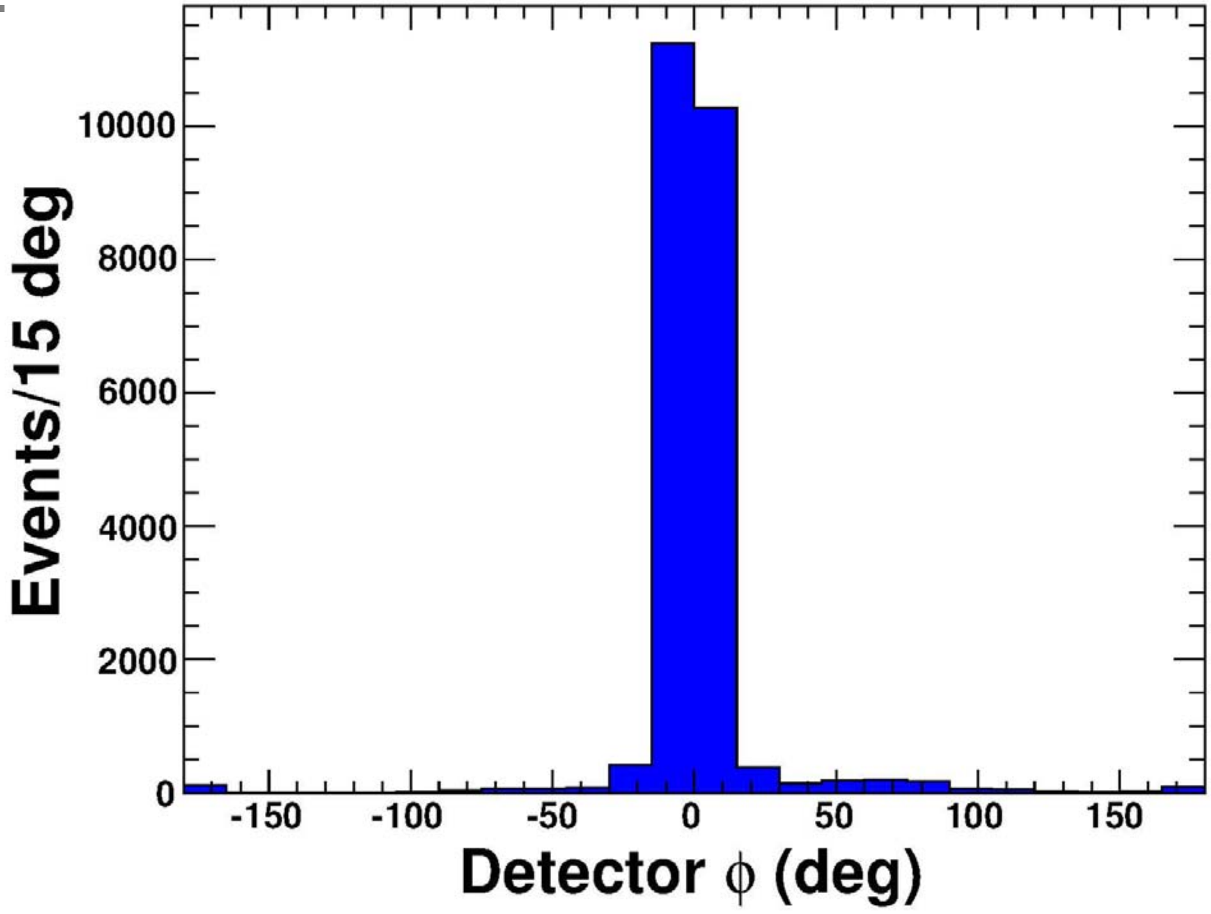


Fig. 22- Kinematic Distributions

- Compare background predictions and data
- No evidence for new physics

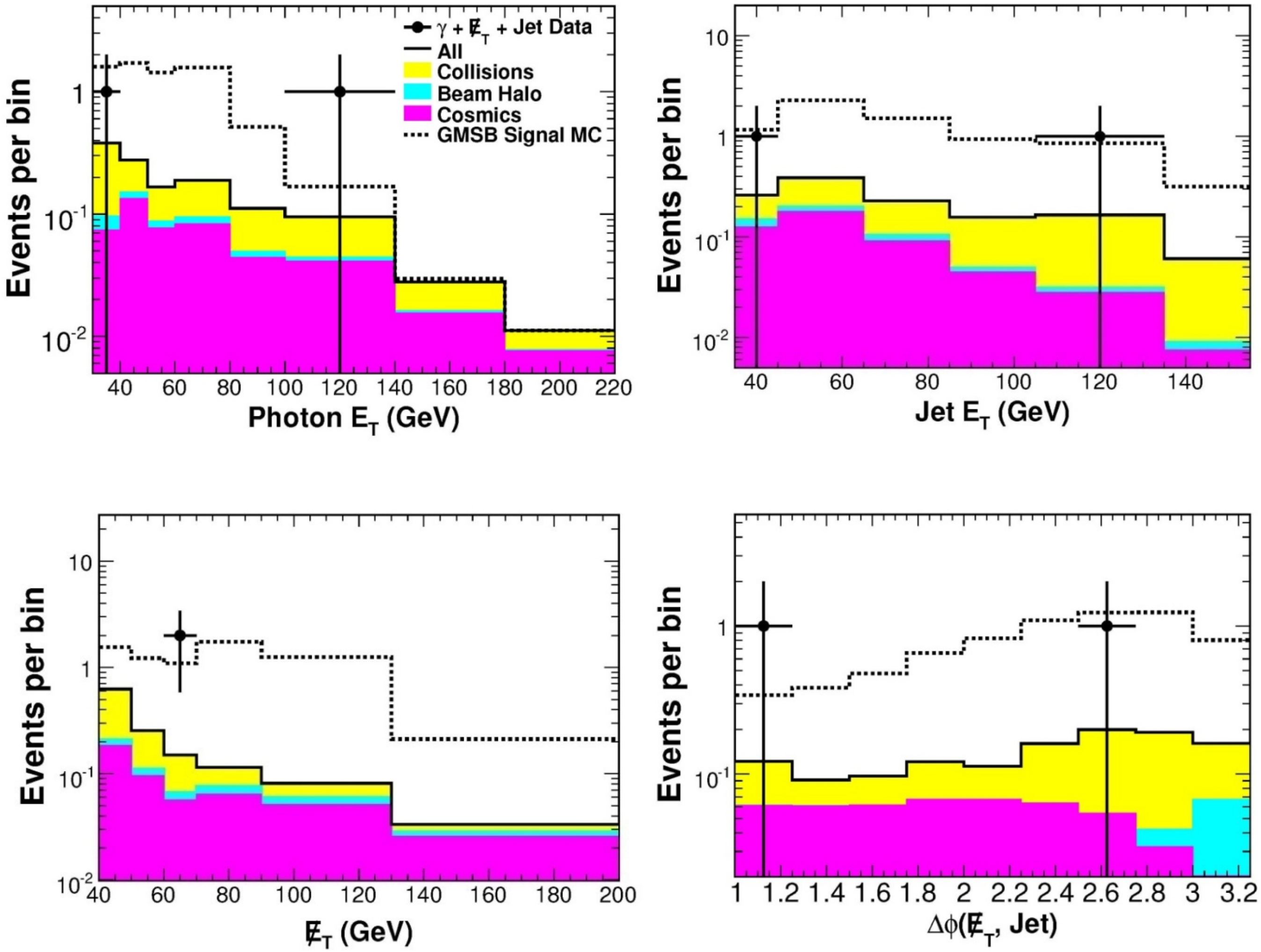
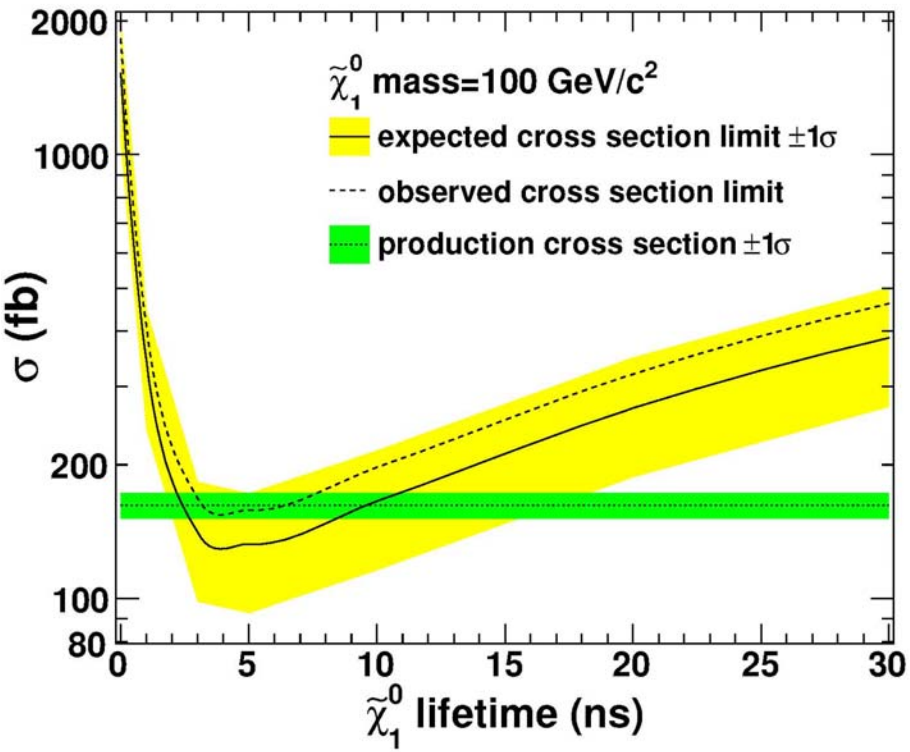
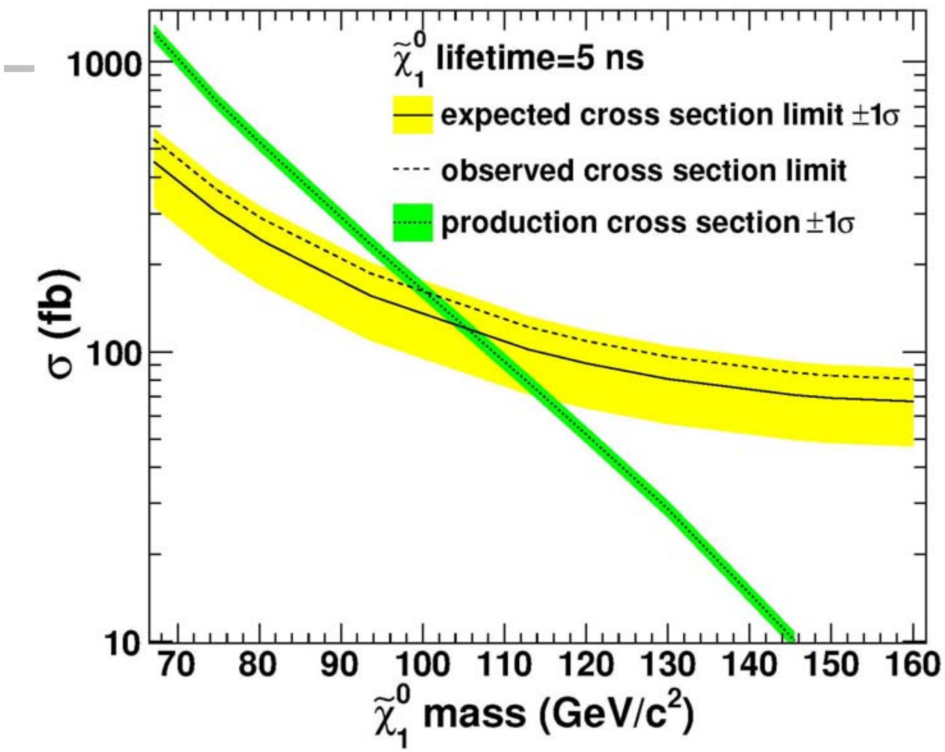


Fig. 23- Expected and Observed Limits and Production Cross Sections





- Limits vs. lifetime for m=100 GeV
- Limits vs. mass for a lifetime of 5 ns

Fig. 24- Results...

The contours of constant 95% C.L. cross section upper limit for the observed number of events